PM Size and Chemical Speciation Profile for Concrete Batching—PM3431

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1 Introduction

This memo presents a new PM profile, PM3431, to be assigned to concrete batching operations. The new profile will be used to replace the assignment of profile PM343 for the categories relevant to concrete batching for all calendar years. The currently assigned PM profile, PM343, was developed based on cement production tests conducted on a cement kiln [1] [2]; so, it isn't representative of emissions from concrete batching operations.

Cement and concrete are often mis-used as interchangeable terms. Cement is an ingredient of concrete while concrete is a mixture of cement, water, fine aggregate (sand) and coarse aggregate (gravel or crushed stone) designed to harden and form durable surfaces and structures. Portland cement is the most commonly manufactured- and used hydraulic cement in the U.S. It is made by cindering finely crushed mineral raw materials at high temperatures in rotary cement kilns. A batch plant is a facility used to store concrete ingredients, combine and mix proportions of concrete ingredients, and dispense concrete mixtures into a mixer-truck for transport to a job site.

2 Methodology

A complete PM profile has two indispensable components, size profile and chemical speciation profile. The development of these two components is described in this section.

2.1 Size profile

A batch plant is a facility which collects and stores concrete ingredients, selects and combines proportions, and dispenses the mixtures to a mixer-truck. The PM (including total PM—TPM, PM_{10} and $PM_{2.5}$) emission factors of such operations can be calculated using the equations in AP-42 Chapter 11.12 [2]. The equations are based upon source tests of centralized- and on-truck mixing facilities. Because on-truck mixing operations using specific controls (e.g. water sprays) are dominant in California, the following equation and parameters (Table 1) are used to estimate the PM emission factors [2] for the purpose of developing particle size profile:

$$E = k(0.0032)\left[\frac{U^a}{M^b}\right] + c \qquad [1]$$

where, E = emission factor in lbs/ton of cement and cement supplement

k = particle size multiplier (dimensionless)
U = wind speed at the material drop point, miles per hour (mph)
M = minimum moisture (% by weight) of cement and cement supplement
a, b = exponents
c = constant

Table 1. Equation parameters for truck mix operations under control

Parameter Category	*k*	*a*	*b*	*c*
TPM*	0.8	1.75	0.3	0.013
PM_{10}	0.32	1.75	0.3	0.0052
$PM_{2.5}$	0.048	1.75	0.3	0.00078

**TPM is total PM*

According to Equation [1] and the parameters in Table 1, the PM_{10}/TPM ratio for a specific site (*U* and *M* are site specific data) can be estimated as $\frac{E_{PM10}}{E_{TPM}} = \frac{0.32\times0.0032\times\left[\frac{U^{1.75}}{M^{0.3}}\right]+0.0052}{0.8\times0.0032\times\left[\frac{U^{1.75}}{M^{0.3}}\right]+0.013} = 0.4$. Similarly, the $PM_{2.5}$/TPM ratio is

$$\frac{E_{PM2.5}}{E_{TPM}} = \frac{0.048\times0.0032\times\left[\frac{U^{1.75}}{M^{0.3}}\right]+0.00078}{0.8\times0.0032\times\left[\frac{U^{1.75}}{M^{0.3}}\right]+0.013} = 0.06.$$

2.2 Chemical species fractions

Cement in the concrete mixtures is the primary contributor to the fugitive particulate matter generated during the concrete batching operations. Therefore, the chemical composition of Portland cement is used to develop the new PM3431 chemical speciation profile. Although the composition of cement varies depending on the application, the basic chemical constituents have to be within certain limits. [3].

In the SPECIATE 4.3 database, there are four PM speciation profiles for Portland cement dust: #2720410, #272042.5, #2720430 and #27204C. These profiles were derived based on the chemical constituents of the National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) 633 Portland cement [4]. The SRM is a certified reference material that is well characterized and used to assure the accuracy and compatibility of measurements throughout the United States and around the world. The SRM 633 series were produced by National Bureau of Standards in 1970's, and they were replaced by the 1880 series in the 1980s. Since the 1880 series are among the most popular SRMs in the catalog of the NIST SRM Program [5], the composition of the SRM 1880 series cements (Table 2) are used to develop the speciation profile for concrete batching in this work.

Table 2. Chemical constituents of NIST SRMs 1880 & 1881

Constituent	*Weight Percentage (%)*	
	SRM 1880	*SRM 1881*
CaO	63.14	58.67
SiO_2	19.82	22.25
Al_2O_3	5.03	4.06
Fe_2O_3	2.91	4.68
SO_3	3.37	3.65
MgO	2.69	2.63
K_2O	0.91	1.17
TiO_2	0.23	0.25
Na_2O	0.28	0.04
SrO	0.06	0.11
P_2O_5	0.29	0.09
Mn_2O_3	0.08	0.26
F	0.1	0.09
Cl	0.02	0.01
ZnO	0.01	0.01
Cr_2O_3	<0.01	<0.01
Loss-on-ignition	1.38	2.01

The PM speciation profiles typically consist of metal elements instead of oxides. To be consistent with the other CARB PM profiles, the weight percentages of the oxides have to be converted to the weight percentages of the related elemental species by multiplying the non-oxygen fraction except for sulfate. The percentage of ‘other’ species consists of oxygen and the loss-on-ignition. To take into account the potential variability among cement products, the final chemical speciation profile of PM3431 is calculated as the average results of SRMs 1880 and 1881.

3 Results and Discussion

The details of the new profile PM3431 concrete batching is summarized in Table 3. The size profile indicates that 40% of the total PM emitted from concrete batching is PM_{10}, and only 6% is $PM_{2.5}$ (Table 3a). This distribution is very different from the existing PM343 size profile, in which PM_{10} and $PM_{2.5}$ fractions are 92% and 62% of the total PM, respectively.

The chemical speciation profile for concrete batching is listed in Table 3b. Since particle-size-specific chemical composition data are not available, a homogeneous chemical composition is assumed for all PM size ranges. That is, the chemical speciation profiles of TPM, PM_{10} and $PM_{2.5}$ are assumed to be the same.

Table 3. Profile PM3431—concrete batching

a. Size fractions

PM size	*PM_{10}/TPM*	*$PM_{2.5}$/TPM*
Weight Fraction	0.40	0.06

b. Chemical Speciation

Species Name	*SAROAD*	*Weight Percentage (%)*		
		TPM	*PM_{10}*	*$PM_{2.5}$*
Aluminum	12101	2.41	2.41	2.41
Calcium	12111	43.53	43.53	43.53
Chromium	12112	0.01	0.01	0.01
Chlorine	12115	0.02	0.02	0.02
Iron	12126	2.65	2.65	2.65
Manganese	12132	0.12	0.12	0.12
Magnesium	12140	1.60	1.60	1.60
Phosphorous	12152	0.08	0.08	0.08
Titanium	12161	0.14	0.14	0.14
Silicon	12165	9.83	9.83	9.83
Zinc	12167	0.01	0.01	0.01
Strontium	12168	0.07	0.07	0.07
Potassium	12180	0.86	0.86	0.86
Sodium	12184	0.12	0.12	0.12
Sulfate	12403	4.21	4.21	4.21
Other	12999	34.24	34.24	34.24
Fluorine	42222	0.10	0.10	0.10
Total		*100.00*	*100.00*	*100.00*

4 Estimated Impacts of the Profile Update on the Emission Inventory

The new profile, PM3431, will replace the current profile PM343 for the inventory categories associated with concrete batching. The related SCCs/EICs are summarized in the Appendix.

Because air quality models currently use coarse and fine particle masses and the emissions of model species are estimated by using the PM size and speciation profiles, the changes resulting from the profile update are discussed in this section.

Compared to the current profile (PM343), the ratios of PM_{10}/TPM and $PM_{2.5}$/TPM in the new profile PM3431 are greatly reduced. Given the 2010 statewide annual average concrete batching TPM emissions of 27.83 tons/day (0.7% of grand total) [6], the estimated PM_{10} emission will be 11.13 tons/day with profile PM3431. This is 56.5% less than the value calculated with profile PM343. Profile PM3431 will only result in 1.67 tons/day of $PM_{2.5}$, a 90.3% reduction from PM343.

Currently, air quality modeling for PM involves five PM model species: OC, EC, sulfate, nitrate, and all other species. However, neither of the profiles (PM3431 or PM343) contains OC, EC and nitrate. Based on 2010 statewide annual average TPM emissions of 27.83 tons/day for concrete batching operations [6], $PM_{2.5}$ sulfate will decrease 10.28 tons/day by applying the new profile PM3431 to the related categories, 99.3% less than the cement kiln value estimated using the inappropriately-assigned profile PM343. Meanwhile, emissions of "other species" of PM2.5 will drop 76.8% due to the profile change (Table 4b). The emissions of PM10 sulfate and all other species caused by the profile update will decrease as well, but they are not presented in Table 4.

Table 4. . Changes on Emissions Using Updated Concrete Batching PM2.5 Profile—PM3431 (2010 Statewide Annual Average)

a. The impact of PM size profile update

State Annual Ave. Emissions	*Using Current PM343 (tons/day)*	*Using New PM3431 (tons/day)*	*Change*	
			Emissions (tons/day)	*Percentage*
PM_{10}	25.60	11.13	-14.47	-56.5%
$PM_{2.5}$	17.25	1.67	-15.58	-90.3%

b. The impact of $PM_{2.5}$ chemical speciation profile update

State Annual Ave. Emissions	*Using Current PM343 (tons/day)*	*Using New PM3431 (tons/day)*	*Change*	
			Emissions (tons/day)	*Percentage*
$PM_{2.5}$—OC	0	0	0	N/A
$PM_{2.5}$—EC	0	0	0	N/A
$PM_{2.5}$—Nitrate	0	0	0	N/A
$PM_{2.5}$—Sulfate	10.35	0.07	-10.28	-99.3%
$PM_{2.5}$—Other species	6.90	1.60	-5.30	-76.8%

5 Version Control

This section will be completed after management approval and after the CEIDARS FRACTION table, PMSIZEPROFILE table and PMCHEMPROFILE table are updated. Version information from CEIDARS FRACTION table will be copied here.

References:

1. *California Air Resources Board Main Speciation Profiles*, 2013, California Air Resources Board.
2. *AP 42 Compilation of Air Pollutant Emission Factors*. 5 ed. Vol. I. US Public Health Service.
3. *Report to Congress--Study on Increasing the Usage of Recovered Mineral Components in Federally Funded Projects Involving Procurement of Cement or Concrete to Address the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users*, 2008, U.S. Environmental Protection Agency in conjunction with the U.S. Department of Transportation and the U.S. Department of Energy.
4. Hsu, Y. and F.J. Divita, *SPECIATE Version 4.3*, 2011, US EPA.
5. Siebera, J., et al., *Standard Reference Materials for Cements.* Cement and Concrete Research, 2002. **32**(12): p. 8.
6. *CEIDARS*, 2012, California Air Resources Board.

Appendix. EICs/SCCs to be associated with concrete batching profiles

EIC/SCC	*Names*			
47035	MINERAL PROCESSES	PRODUCTION	CEMENT CONCRETE	
30500607	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	RAW MAT UNLOADING
30500608	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	RAW MAT PILES
30500609	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	PRIMARY CRUSHING
30500610	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	SECOND CRUSHING
30500611	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	SCREENING
30500612	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	RAW MAT TRANSFER
30500613	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	RAW MAT GRIND/DRY
30500614	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	CLINKER COOLER
30500615	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	CLINKER PILES
30500616	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	CLINKER TRANSFER
30500617	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	CLINKER GRINDING
30500618	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	CEMENT SILOS
30500619	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	CEMENT LOAD OUT
30500621	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	PULV COAL KILN FEED
30500624	MINERAL PRODUCTS	CEMENT MFG	RAW MILL	FEED BELT
30500626	MINERAL PRODUCTS	CEMENT MFG	RAW MILL	AIR SEPARATOR
30500627	MINERAL PRODUCTS	CEMENT MFG	FINISH GRINDING MILL	FEED BELT
30500629	MINERAL PRODUCTS	CEMENT MFG	FINISH GRINDING MILL	AIR SEPARATOR
30500699	MINERAL PRODUCTS	CEMENT MFG	DRY PROCESS	OTHER
30500707	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	RAW MAT UNLOADING
30500708	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	RAW MAT PILES
30500709	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	PRIMARY CRUSHING
30500710	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	SECONDARY CRUSHING
30500711	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	SCREENING
30500712	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	RAW MAT TRANSFER
30500714	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	CLINKER COOLER
30500716	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	CLINKER TRANSFER
30500717	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	CLINKER GRINDING
30500718	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	CEMENT SILO

Concrete batching

30500719	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	CEMENT UNLOADING
30500728	MINERAL PRODUCTS	CEMENT MFG	FINISH GRINDING MILL	WEIGHT HOPPER
30500799	MINERAL PRODUCTS	CEMENT MFG	WET PROCESS	OTHER
30501101	MINERAL PRODUCTS	CONCRETE BATCHING	GENERAL	
30501106	MINERAL PRODUCTS	CONCRETE BATCHING	SAND/AGGREGATE	TRANSFER TO BINS
30501107	MINERAL PRODUCTS	CONCRETE BATCHING	CEMENT UNLOADING	ELEVATED SILOS
30501108	MINERAL PRODUCTS	CONCRETE BATCHING	WEIGHT HOPPER	LOADING
30501109	MINERAL PRODUCTS	CONCRETE BATCHING	MIXER LOADING	
30501110	MINERAL PRODUCTS	CONCRETE BATCHING	TRANSIT MIX TRUCK	LOADING
30501111	MINERAL PRODUCTS	CONCRETE BATCHING	DRY-BATCH TRUCK	LOADING
30501112	MINERAL PRODUCTS	CONCRETE BATCHING	MIXING WET	
30501113	MINERAL PRODUCTS	CONCRETE BATCHING	MIXING DRY	
30501114	MINERAL PRODUCTS	CONCRETE BATCHING	TRANSFERRING	CONVEYOR/ELEVATOR
30501115	MINERAL PRODUCTS	CONCRETE BATCHING	STORAGE	BINS/HOPPERS
30501120	MINERAL PRODUCTS	CONCRETE BATCHING	ASBEST/CEMENT PDT	
30501121	DUMMY NAME 10-30-81	INDUSTRIAL PROCES-MI	CONCRETE BATCHING	ROAD SURFACE
30501199	MINERAL PRODUCTS	CONCRETE BATCHING	NOT CLASSIFIED	OTHER
30510102	MINERAL PRODUCTS	BULK MATERIALS	CONVEYORS	CEMENT
30510202	MINERAL PRODUCTS	BULK MATERIALS	STORAGE BINS	CEMENT
30510302	MINERAL PRODUCTS	BULK MATERIALS	OPEN STOCKPILES	CEMENT
30510402	MINERAL PRODUCTS	BULK MATERIALS	UNLOADING OPERATN	CEMENT
30510502	MINERAL PRODUCTS	BULK MATERIALS	LOADING OPERATION	CEMENT
43043070180000	MINERAL PROCESSES	PRODUCTION	CEMENT CONCRETE	INDUSTRIAL PROCESSES
43043670180000	MINERAL PROCESSES	STORAGE PILES	CEMENT CONCRETE	INDUSTRIAL PROCESSES
43099570180000	MINERAL PROCESSES	OTHER	CEMENT CONCRETE	INDUSTRIAL PROCESSES
43099570780000	MINERAL PROCESSES	OTHER	SAND/AGGREGATE	INDUSTRIAL PROCESSES